680-G

NEWARK PUBLIC LIBRARY

MAR 23 1982

U. S. GOVT. PUBS.
DEPOSITORY 378

Fossil Corals From Midway Atoll

GEOLOGICAL SURVEY PROFESSIONAL PAPER 680-G

I 19.16:

Fossil Corals From Midway Atoll

By JOHN W. WELLS

GEOLOGY OF THE MIDWAY AREA, HAWAIIAN ISLANDS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 680-G

A description of corals from two cored holes through the reef cap of Midway atoll

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *Secretary*

GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

Library of Congress Cataloging in Publication Data

Wells, John West, 1907-
Fossil corals from Midway atoll.

(Geology of the Midway Area, Hawaiian Islands)
(Geological Survey professional paper ; 680-G)
Bibliography: p.
Supt. of Docs. no.: I 19.16:680-G
1. Corals, Fossil. 2. Paleontology—Midway Islands. I. Title. II. Series. III. Series: Geological Survey professional paper ; 680-G.
QE778.W43 563'.6'099699 81-607875 AACR2

**For sale by the Distribution Branch, U.S. Geological Survey,
604 South Pickett Street, Alexandria, VA 22304**

CONTENTS

	Page
Abstract	G1
Introduction	1
Acknowledgments	1
Living coral fauna of the Hawaiian Archipelago	1
Post-Miocene fossil corals	1
Miocene corals	1
Systematic descriptions	3
References cited	7

ILLUSTRATIONS

[Plates follow index]

PLATES 1-3. Miocene corals
1. *Stylophora*
2. *Seriatopora, Pocillopora, Acropora, Plesiastrea*
3. *Favia, Favites, Galaxea*

	Page
FIGURE 1. Map of Midway atoll, showing location of drill holes	G2
2. Stratigraphic distribution of fossil reef corals from Midway drill holes	3

TABLE

	Page
TABLE 1. Living shallow-water corals of the Hawaiian Islands and fossil corals from Midway	G2

CONVERSION FACTORS

Metric unit		Inch-Pound equivalent
Length		
millimeter (mm)	= 0.03937	inch (in)
meter (m)	= 3.28	feet (ft)
kilometer (km)	= .62	mile (mi)
Area		
square meter (m^2)	= 10.76	square feet (ft^2)
square kilometer (km^2)	= .386	square mile (mi^2)
hectare (ha)	= 2.47	acres
Volume		
cubic centimeter (cm^3)	= 0.061	cubic inch (in^3)
liter (L)	= 61.03	cubic inches
cubic meter (m^3)	= 35.31	cubic feet (ft^3)
cubic meter	= .00081	acre-foot (acre-ft)
cubic hectometer (hm^3)	=810.7	acre-feet
liter	= 2.113	pints (pt)
liter	= 1.06	quarts (qt)
liter	= .26	gallon (gal)
cubic meter	= .00026	million gallons (Mgal or 10^6 gal)
cubic meter	= 6.290	barrels (bbl) (1 bbl=42 gal)
Weight		
gram (g)	= 0.035	ounce, avoirdupois (oz avdp)
gram	= .0022	pound, avoirdupois (lb avdp)
metric tons (t)	= 1.102	tons, short (2,000 lb)
metric tons	= 0.9842	ton, long (2,240 lb)
Specific combinations		
kilogram per square centimeter (kg/cm^2)	= 0.96	atmosphere (atm)
kilogram per square centimeter	= .98	bar (0.9869 atm)
cubic meter per second (m^3/s)	= 35.3	cubic feet per second (ft^3/s)

Metric unit		Inch-Pound equivalent
Specific combinations—Continued		
liter per second (L/s)	= .0353	cubic foot per second
cubic meter per second per square kilometer [$(m^3/s)/km^2$]	= 91.47	cubic feet per second per square mile [$(ft^3/s)/mi^2$]
meter per day (m/d)	= 3.28	feet per day (hydraulic conductivity) (ft/d)
meter per kilometer (m/km)	= 5.28	feet per mile (ft/mi)
kilometer per hour (km/h)	= .9113	foot per second (ft/s)
meter per second (m/s)	= 3.28	feet per second
meter squared per day (m^2/d)	= 10.764	feet squared per day (ft^2/d) (transmissivity)
cubic meter per second (m^3/s)	= 22.826	million gallons per day (Mgal/d)
cubic meter per minute (m^3/min)	=264.2	gallons per minute (gal/min)
liter per second (L/s)	= 15.85	gallons per minute
liter per second per meter [(L/s)/m]	= 4.83	gallons per minute per foot [(gal/min)/ft]
kilometer per hour (km/h)	= .62	mile per hour (mi/h)
meter per second (m/s)	= 2.237	miles per hour
gram per cubic centimeter (g/cm^3)	= 62.43	pounds per cubic foot (lb/ft^3)
gram per square centimeter (g/cm^2)	= 2.048	pounds per square foot (lb/ft^2)
gram per square centimeter	= .0142	pound per square inch (lb/in^2)
Temperature		
degree Celsius (°C)	= 1.8	degrees Fahrenheit (°F)
degrees Celsius (temperature)	=[(1.8×°C)+32]	degrees Fahrenheit

FOSSIL CORALS FROM MIDWAY ATOLL

By JOHN W. WELLS

ABSTRACT

Fossil corals were recovered from the cores and cuttings of the two drill holes made on Midway atoll in 1965. Reef-building scleractinian corals were relatively continuous from near the surface to a depth of 1,143 ft. Above 494 ft, six species representing five genera were recognized, all identical with the living Hawaiian reef fauna; the age range was Pliocene to Holocene. At and below 494 ft was a poorly preserved surface reef fauna of Miocene age, represented by 10 genera and 13 species; this fauna was unlike that of similar age found in the drill holes at Bikini and Enewetak (formerly Eniwetok).

INTRODUCTION

In two previous reports (Wells 1954b, 1964), the writer described fossil corals recovered from drill holes on Bikini and Enewetak (formerly Eniwetok) Atolls. At Bikini, two coral zones were recognized: (1) Pliocene-Pleistocene from the surface to a depth of about 700 ft and (2) middle and upper Miocene from 725 to 1,100 ft. At Enewetak, from the surface to 620 ft, reef corals were scarce and poorly preserved; no forms characteristic of Pliocene or Pleistocene were found between Miocene and Holocene assemblages. Below 620 ft, a Miocene assemblage was found, extending to at least 3,100 ft. Below this, an Eocene fauna was recovered from 4,078 to 4,100 ft.

At Midway atoll, two deep holes were drilled in 1965 (Ladd and others, 1970). From the hole on Sand Island (fig. 1), drilled to the basalt at 568 ft, 11 core samples from depths of 13 to 331 ft contained well-preserved reef corals, all belonging to genera and species still living at Midway and the main Hawaiian Islands. No corals were found in samples from 331 to 501 ft. The deeper hole on the reef, opposite Sand Island, was drilled to 1,564 ft into the basalt basement (see Ladd and others, 1970). Core recovery was high, and corals were found in 63 samples from 70 to 1,143 ft. Forty-nine of these were in the Miocene from 494 to 1,143 ft. Above 494 ft in the post-Miocene, preservation was good except for a few recrystallized remains. In the Miocene section, preservation was mainly as empty or partly empty molds of fragments of colonial hermatypes.

ACKNOWLEDGMENTS

Warren Blow of the Smithsonian Institution aided in the preparation of the material. Many of the photographs were prepared by Robert H. McKinney and Haruo E. Mochizuki of the U.S. Geological Survey.

LIVING CORAL FAUNA OF THE HAWAIIAN ARCHIPELAGO

During the drilling operations at Midway, corals living on the reefs at Midway and Kure were collected by H.S. Ladd; collections were also made in 1968 and 1969 by Dana (1971). These collections were studied by the writer in connection with the fossils recovered from the Midway drill holes. Table 1 tabulates (1) the living shallow-water (less than 120 ft) hermatypic corals in the main Hawaiian Islands, Midway, and Kure and (2) post-Miocene and Miocene fossil corals on Midway.

Most of the living forms are very widespread tropical Pacific species; only a handful of apparently endemic forms was found, including *Cyphastrea ocellina*, *Montipora flabellata*, *Porites duerdeni*, *Psammocora brighami*, and *P. verrilli*. At Midway and Kure, some 1,000 miles northwest of the main Hawaiian group, only 16 of the 33 recorded species from Hawaii have been found, a not unexpected diversity attenuation.

POST-MIOCENE FOSSIL CORALS

The six species found in samples younger than the Miocene (fig. 2) from the Sand Island and reef holes are all shallow-water reef types living today in the Hawaiian Archipelago, with the exception of *Leptoseris* sp. cf. *L. incrustans*, which has not yet been definitely recorded from localities nearer than the Marshall Islands, although other species of *Leptoseris* occur in the main Hawaiian Islands at depths below about 120 ft (Vaughan 1907). Notably lacking is *Stylophora*, relatively abundant in the Miocene section of the Midway reef hole, as well as *Favia*, *Favites*, *Plesiastrea*, and *Galaxea*. On the other hand, *Acropora*, which occurs in the Midway Miocene and is living in Hawaii, was not found in the post-Miocene section. No evidence as to the age—Pliocene or Pleistocene—is afforded by the meager post-Miocene coral assemblage.

MIOCENE CORALS

The Miocene coral assemblage (table 1; fig. 2) bears little resemblance to that found in the Bikini and Enewetak drill holes (Wells 1954b, 1964) or to that in the Miocene of Borneo, Java, and Palau. This Midway Miocene assemblage lacks such characteristic species as *Seriatopora ornata*, *S. delicatula*, *S. micrommata*,

READEX FICHE best copy available

TABLE 1.—*Living shallow-water corals of the Hawaiian Islands and fossil corals from Midway*

Species	Living Corals			Fossil Corals	
	Holocene			Post-Miocene	Miocene
	Hawaii	Midway	Kure	Midway	
Acropora cytherea (Dana)	X	-----	--	-----	----
humilis (Dana)	X	-----	--	-----	----
valida (Dana)	X	-----	--	-----	----
Alveopora verrilliana Dana	X	-----	--	-----	----
Coscinaraea sp.	X	-----	--	-----	----
Leptastrea bottae (M.E. & H.)	X	-----	--	-----	----
Montipora dilatata Studer	X	-----	--	-----	----
flabellata Vaughan	X	-----	--	-----	----
patula Verrill	X	-----	--	-----	----
Porites brighami Vaughan	X	-----	--	-----	----
duerdeni Vaughan	X	-----	--	-----	----
lanuginosa Studer	X	-----	--	-----	----
pukoensis Vaughan	X	-----	--	-----	----
Psammocora brighami Vaughan	X	-----	--	-----	----
verrillli Vaughan	X	-----	--	-----	----
Montipora verrilli Vaughan	X	X	X	-----	----
venosa (Ehrenberg)	X	X	X	-----	----
Fungia scutaria Lamarck	X	X	X	-----	----
Leptastrea purpurea (Dana)	X	X	X	-----	----
Montipora verrucosa (Lamarck)	X	X	X	-----	----
Pavona varians Verrill	X	X	X	-----	----
Pocillopora damicornis (Linnaeus)	X	X	X	-----	----
meandrina Dana	X	X	X	-----	----
Porites compressa Dana	X	X	X	-----	----
evermanni Vaughan	X	X	X	-----	----
(*Synaraea*) *hawaiiensis* Vaughan	X	X	X	-----	----
Psammocora stellata Verrill	X	X	X	-----	----
Cyphastrea ocellina (Dana)	X	X	X	X	----
Pavona clavus Dana	X	X	X	X	----
Pocillopora ligulata Dana	X	X	X	X	----
Porites lobata Dana	X	X	X	X	----
Pavona maldivensis (Gardiner)	----	X	X	X	----
Montipora tuberculosa (Lamarck)	----	X	--	-----	----
Leptoseris cf. *incrustans* (Quelch)	----	-----	--	X	----
Acropora sp.	----	-----	--	-----	X
Favia sp. A,B,C	----	-----	--	-----	X
Favites cf. *chinensis* (Verrill)	----	-----	--	-----	X
Galaxea haligena Felix	----	-----	--	-----	X
Pocillopora cf. *hemprichi* Ehrenberg	----	-----	--	-----	X
Porites sp. A,B,C	----	-----	--	-----	X
Stylophora gemmans Gerth	----	-----	--	-----	X
pistillata (Esper)	----	-----	--	-----	X
Seriatopora cf. *hystrix* Dana	----	-----	--	-----	X
Plesiastrea cf. *curta* (Dana)	----	-----	--	-----	X

Dictyaraea micrantha, and *Alveopora polyacantha*. The relative abundance of *Stylophora*, *Pocillopora*, and *Porites*, genera lacking or uncommon in the Bikini and Enewetak Miocene, suggests a reef-flat rather than a lagoonal environment. Only one species, *Stylophora gemmans*, relating to the Miocene faunas of Lau, Fiji, and Eua, Tonga (Hoffmeister, 1945), is found at Midway. Two Midway species, *S. gemmans* Gerth (Miocene, Borneo) and *Galaxea haligena* Felix (Miocene, Borneo; Pliocene, Java), were originally described from Indonesia.

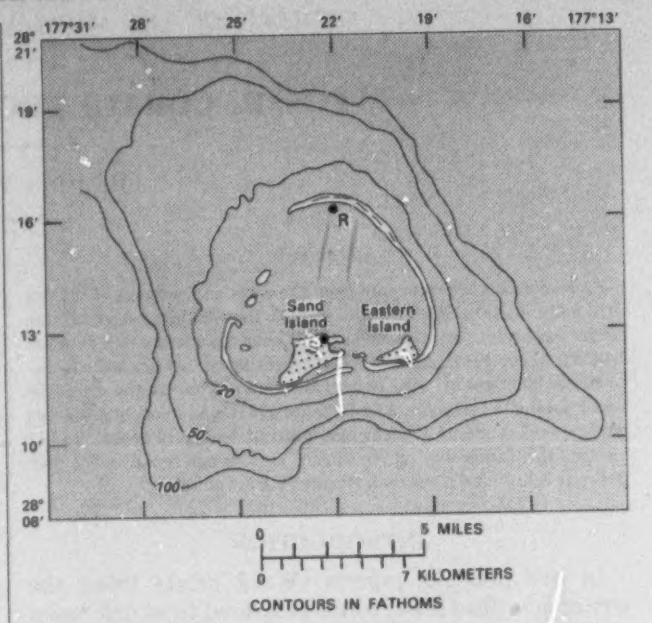


FIGURE 1.—Map of Midway atoll, showing location of drill holes. S, Sand Island hole; R, reef hole.

Stylophora, *Seriatopora*, *Favia*, *Favites*, and *Galaxea* are genera absent from the post-Miocene and Holocene of the Hawaiian Archipelago and the Far Eastern Pacific; their presence in the Midway Miocene indicates a much broader distribution, at that time, of these common tropical Pacific genera.

SYSTEMATIC DESCRIPTIONS

Sample localities are followed by numbers indicating depths in feet in the Sand Island or reef holes; for example, Sand Island hole 65–66, 331; reef hole 304–312, 361.

Genus STYLOPHORA Schweigger 1819

Stylophora pistillata (Esper 1795)

Plate 1, figures 1–6

Stylophora pistillata Veron and Pichon 1976, p. 66, figs. 131–150 (synonymy)

Two growth forms (ecomorphs), *pistillata* and *mordax*, of this highly polymorphic species as revised by Veron and Pichon occur in 34 of the 45 core samples from depths of 590 to 1,061 ft. Ecomorph *pistillata*, which has branches 8–15 mm thick, is much less

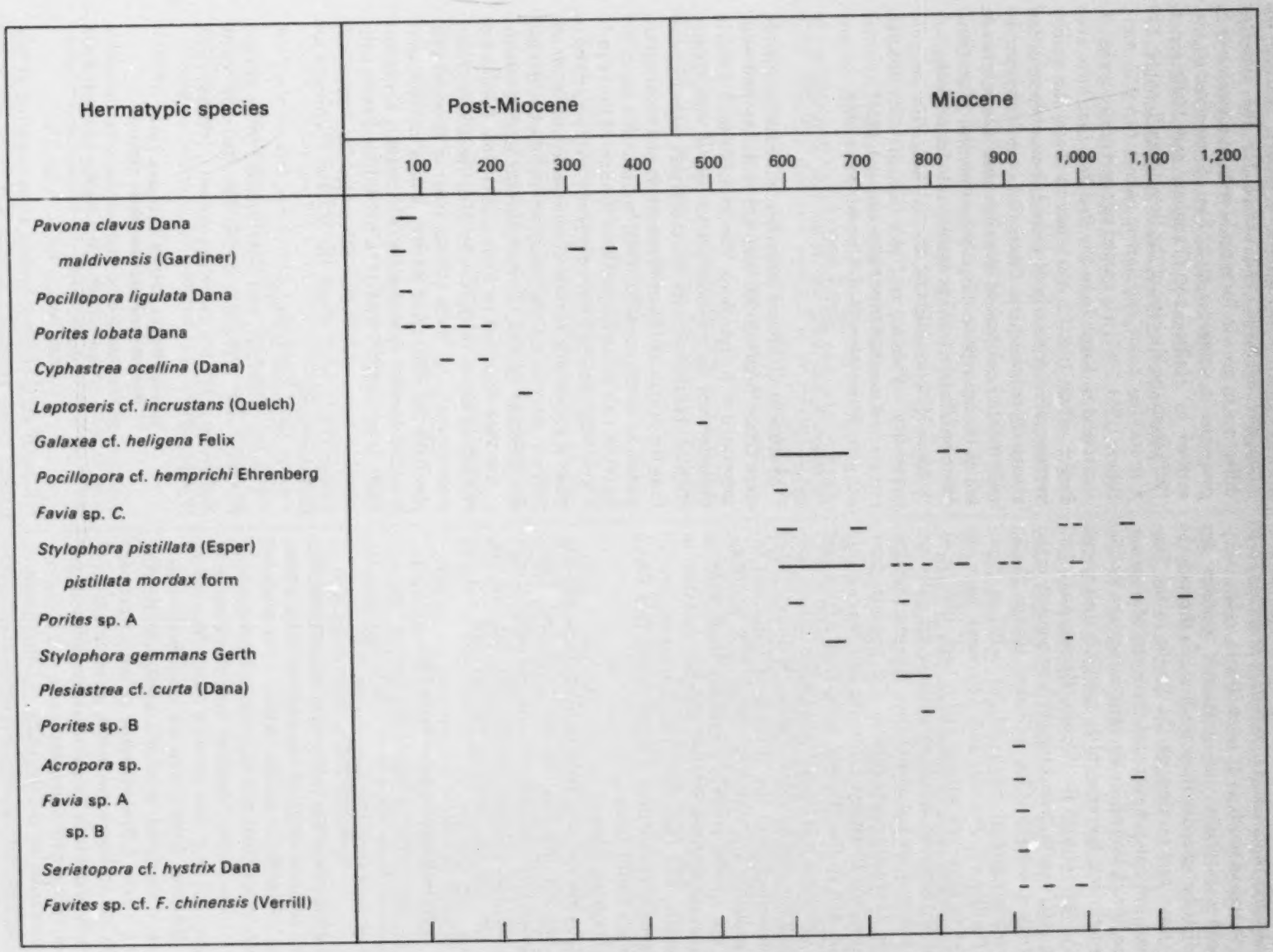


FIGURE 2.—Stratigraphic distribution of fossil reef corals from Midway drill holes. S, Sand Island hole; R, reef hole.

common (8 samples) than is the *mordax* form (26 samples) which has compressed to flabellate branches 10–15 mm thick and as much as at least 50 mm wide.

Stylophora pistillata and ecomorph *mordax* are widely distributed today from the Red Sea through the Indian Ocean and on through the Pacific to the Tuamotus but are not yet recorded from the Marquesas, Johnston Island, Hawaii, or the extreme eastern Pacific. Fossil specimens, however, of *S. pistillata* (ecomorph *mordax*), together with *Pocillopora*, *Porites*, and *Plesiastrea* sp. cf. *P. curta*, were dredged from a guyot on the Nasca Ridge at a depth of 950 m (Fisher, 1958, p. 22–23); from another guyot at depths of 210 to 227 m, *Stylophora*, *Pocillopora*, *Porites*, and *Leptoseris* were reported by Durham (*in* Allison and others, 1967, p. 4). The ages of these two fossil assemblages are quite uncertain, but they are not earlier than Miocene (Holden, 1967, p. 3). There are many records of *S. pistillata* from the Pliocene and Pleistocene from the Red Sea east into Indonesia, and in the Miocene from East Africa east through Indonesia into the western Pacific (Bikini, Enewetak) and the north-central Pacific (Midway). Other species described from the Miocene of India and Indonesia probably are within the range of *S. pistillata*, because the species criteria commonly used, such as calice dimensions, hoods or their absence, variation in septal details, and coenosteal ornamentation, are all highly variable even within a single colony (see Veron and Pichon's (1976) figures).

Age.—Miocene, Midway.

Locality.—Midway, reef hole, *pistillata* form: 590–595, 961–962, 963–964, 990–993, 993–994, 1,057–1061, 1,061–1,066; *mordax* form: 595–600, 613, 619, 627–629, 631–636, 638, 651, 657, 662, 671–676, 678–679, 684, 701, 746, 751, 754, 781, 783, 826–831, 831–832, 836–837, 842, 879–880, 882–883, 901–906, 970–971.

Stylophora gemmans Gerth 1923

Plate 1, figures 7–9

Stylophora gemmans Gerth 1923, p. 98, pl. 7, fig. 9
?Stylophora verrucosa Gerth 1923, p. 97, pl. 7, figs. 7, 8
Hoffmeister 1945, p. 300, pl. 11, figs. A, B

Three samples from the reef hole at 659, 671–676, and 970 ft show external molds of what appear to have been encrusting or laminate coralla, which have scattered verrucaelike projections bearing calices; these features agree with those of the fragment from the Miocene of Borneo described as *S. gemmans* by Gerth. The calices range in diameter from 0.4 to 0.6 mm, flush with a slightly raised sharp rim or with a raised rounded rim, and lacking hoods. A directive pair of the six primary septa joins the styliform columella. A second cycle of short septa is found in some calices. Intercalicular coenosteum surface evenly spinulose.

The *S. verrucosa* of Gerth (1923) and the specimen later identified by Hoffmeister (1945) from the Miocene of Lau (Fiji) were broken branches bearing pocilloporoid verrucae, and except for the apparent difference in growth form could well be the same as *S. gemmans*. A verrucate *Stylophora*, *S. monticulosa*, described by Hoffmeister (Vaughan and Hoffmeister, 1925) from the Miocene of the Dominican Republic, has a branching habit and larger calices (0.5–0.75 mm). Scheer (1964, 1967) has named two verrucate species, *S. wellsi* and *S. hassi*, from the Red Sea, that have even larger calices (0.8–1.2 mm), but in these, the stubby verrucae are irregularly developed, some of them giving rise to short branchlets. These Holocene forms may be only stunted colonies of *S. subseriata* (Ehrenberg) in which the branches commonly have similar projections, the more distal of which develop into branchlets.

Age.—Miocene, Midway; Borneo; Lau, Fiji.

Locality.—Midway, reef hole: 659, 671–676, 970–971.

Genus SERIATOPORA Lamarck 1816
Seriatopora sp. cf. S. hystrix Dana 1846

Plate 2, figures 1, 2

Seriatopora hystrix Veron and Pichon 1976, p. 58, figs. 91–118 (synonymy)

Specimens of broken branches, all external molds, were found between 946 and 993 ft in the reef hole, associated with *Stylophora*. The branches are 2–5 mm in diameter and have calices 0.6–0.8 mm in size. Calices slightly protuberant with distal margins more elevated than the proximals. Coenosteum finely and evenly granulated, subcostate near calicular margins. Six septa, the directive pair being aligned with the axis of the branch.

The fragments are not sufficiently well preserved to make a reasonably certain specific determination, but they certainly do not represent either of the two distinctive Miocene species, *S. microminata* and *S. ornata*, which were described by Felix (1921) from Borneo and recognized again in Borneo by Umbgrove (1929) and, more recently, by Wells (1954a, 1964) in Miocene samples from the Bikini and Enewetak drill cores. A third Miocene species, *S. delicatula* Felix (1921; Umbgrove 1929), is probably *S. hystrix*, a living Indo-Pacific polymorphic form elaborately illustrated by Veron and Pichon (1976), with which the Midway fragments are here compared.

Age.—Miocene, Midway.

Locality.—Midway, reef hole: 946–951 (with *Favites*, *Porites*, and *Stylophora*); 958–959, 961–962 (with *Stylophora*); 963–964 (with *Stylophora*); 990–993 (with *Stylophora*).

Genus POCILLOPORA Lamarck 1816
Pocillopora ligulata Dana 1846

Pocillopora ligulata Dana 1846, p. 529, pl. 50, figs. 3, 3a
Vaughan 1907, p. 94, pl. 14, figs. 1, 1a; pl. 17, figs. 2, 2a; pls. 18–21
Wells 1954a, p. 413, pl. 99, figs. 3, 4

Several algal-crusted, broken stout branches of this typical living Hawaiian species was found at 79 and

81 ft in the Midway reef hole. On one fragment, the calicular surface is well preserved and shows the characteristic septa and columella.

Age.—Pleistocene and Holocene, Midway.

Locality.—Midway, reef hole: 79, 80–81.

Pocillopora sp. cf. P. hemprichi Ehrenberg 1834

Plate 2, figures 3, 4

Pocillopora hemprichi Ehrenberg 1834, p. 128
Milne Edwards and Haime 1860, p. 304
Klunzinger 1879, p. 29, pl. 7, fig. 1; pl. 8, fig. 13

Pieces of stout branches that have small appressed verrucae belong to the species group having closely set deep calices lacking septa and columella and marked by finely spinulose coenosteum. These specimens do not pertain to the few *Pocillopora* species reported from the Miocene of the Indo-Pacific (*P. eydouxi*, *P. jenkinsi*, *P. ligulata*, and *P. solida*), all forms having well-developed septa and columella. Comparison with Holocene species lacking septa and columella is difficult, but among the 25 or more nominal aseptate forms, only one, *P. hemprichi* from the Red Sea, appears to be related to the Midway fossils by its robust, often flattened or subflabellate branches having appressed verrucae.

Age.—Miocene, Midway.

Locality.—Midway, reef hole: 595–600, 627–629, 631–636, 638, 641, 661–662, 678–679, 684, 809–810, 831–832.

Acropora Oken 1815
Acropora sp.

Plate 2, figures 5, 6

Two small external molds of calicular surfaces cannot be identified further, although differences in corallite size suggest two different species.

Acropora is known to be still living in Hawaiian waters (Maragos, 1977).

Age.—Miocene, Midway; Pleistocene and Holocene, Hawaii.

Locality.—Midway, reef hole: 901–906, 946–951.

Genus PAVONA Lamarck 1801
Pavona clavus Dana 1846

Pavona clavus Dana 1846, p. 332, pl. 24, fig. 4
Wells 1954a, p. 441, pl. 152, fig. 1, 2 (synonymy)

One specimen, part of a massive corallum, is placed in this variable and widespread Indo-Pacific reef species.

Age.—Pleistocene, Midway; Pliocene and Pleistocene, Indonesia, New Caledonia; subfossil and Holocene, Indo-Pacific.

Locality.—Midway, Sand Island hole: 78–83; living at Midway.

Pavona maldivensis (Gardiner 1905)

Siderastrea maldivensis Gardiner 1905, p. 935, pl. 89, fig. 3
Pavona maldivensis Matthai 1948, p. 182, pl. 6 fig. 20; pl. 12, fig. 47
Pavona (Pseudocolumnastraea) pollicata Wells 1954a, p. 483, pl. 153, figs. 1–3
Dana 1970, p. 82
Leptoseris incrustans Dana 1970 (*non* Quelch) p. 82
?*Heliastrea digitata* Duncan 1880, p. 89, pl. 21, figs. 7, 8

A variant of this species occurs on the living reefs at Midway and as fossil in the upper part of the drill holes. The calicular centers on the thin laminar expansions are strongly individualized, often closely packed together, 2–2.5 mm in overall diameter, elevated to 3.5 mm, erect or inclined, or distorted by intratentacular increase, with 20–45 alternating septa. From the laminar sheets arise pollicate elevations bearing smaller, less elevated calices with 20–30 septa.

Age.—Post-Miocene and Holocene, Midway; Holocene, Indo-Pacific (Madagascar east to Tahiti and Tuamotus, Hawaii).

Locality.—Midway, Sand Island hole: 65–66, 331; reef hole: 304–312, 361.

Genus LEPTOSERIS Milne Edwards and Haime 1849
Leptoseris sp. cf. L. incrustans (Quelch 1886)

Leptoseris incrustans Wells 1954a, p. 444, pl. 154, figs. 5–7 (synonymy)

One fragment, very poorly preserved, is referred to this Pacific pavonid, living normally at 15–80 m, but not known certainly to be still living in Hawaiian waters. The specimen from Nero Bank erroneously identified by the writer in Dana (1971), is *Pavona maldivensis*.

Age.—Pliocene and Pleistocene, Midway.

Locality.—Midway, reef hole: 243–248.

Genus PORITES Link 1807
Porites lobata Dana 1846

Porites lobata Dana 1846, p. 562, pl. 55, fig. 1
Vaughan 1907, p. 196, pl. 81, figs. 1, 2; pls. 82, 83, 84, figs. 1, 2; pl. 85, fig. 1.

This widespread Indo-Pacific species is common in the Midway core samples from 70 to 185 ft in various states of preservation. It has not been recorded from reef deposits older than subrecent, mainly because of the difficulty in determining *Porites* species when well-preserved calicular surfaces are lacking.

Age.—Post-Miocene and Holocene, Midway.

Locality.—Midway, Sand Island hole: 113–118, 141–142, 161, 180–185; reef hole: 70, 87, 103, 111, 129, 134, 145–146, 154.

Porites sp. A

Fragments of a massive corallum were found in several core samples. Cut surfaces and badly worn calices show corallites 0.75–1.25 mm in diameter and having 12 septa, but further details cannot be seen well enough to allow closer identification.

Age.—Miocene, Midway.

Locality.—Midway, reef hole: 613, 755, 879–880, 1,067–1,069, 1,130–1,139, 1,142–1,143.

Porites sp. B

Molds in chalky limestone are remnants of a *Porites* that have fingerlike branches 1–1.5 cm in diameter, but no calices are preserved.

Age.—Miocene, Midway.

Locality.—Midway reef hole: 779, 782–783.

Genus FAVIA Oken 1815

Recent species of this widespread Indo-Pacific genus are difficult to discriminate because of broad individual variation; fossil specimens are even more troublesome. Of the 6 samples in the Midway cores, 3 are external molds of a small group of calices, 1 shows only internal structures in section, and 2 are recrystallized fragments having moderately preserved calices. None of these specimens can be referred to any living or fossil species with any degree of certainty and are here placed in three groups:

Favia sp. A

Plate 3, figure 1

Three external molds show slightly elevated calices 8–10 mm in diameter, separated 3–5 mm, united by equal subspinose costae corresponding to all septa. Three cycles of stout septa, equal except in dividing calices. Details of septal margins and columella lacking.

The few characters of the corallum that are preserved are suggestive of the grouping of recent forms referred to as the "*Favia amicorum* complex" by Veron and Pichon (1977, p. 32, figs. 37–44).

Age.—Miocene, Midway.

Locality.—Midway, reef hole: 901–906, 923–924, 1,061–1,066 (with *Stylophora* and *Acropora*).

Favia sp. B

Plate 3, figure 2

Two recrystallized fragments that have moderately well preserved calices are comparable with *F. lizardensis*, a new species from the Great Barrier Reefs, described recently by Veron and Pichon (1977).

Age.—Miocene, Midway.

Locality.—Midway, reef hole: 915–916.

Favia sp. C

Plate 3, figure 4

A poorly preserved transverse section of a fragmentary corallum shows corallites 8–11 mm in diameter, separated by 1–2 mm and united by costae. Septa mostly 16 in number, arranged 8/8, the first 8 with thickened inner ends extending to the axis where they join a very weak columella. The large size of the corallites and small number of septa are a combination uncommon in *Favia*, and a new species may be involved, but it will not be named until data on the nature of the calicular surface are found.

Age.—Miocene, Midway.

Locality.—Midway, reef hole: 590–595.

Genus FAVITES Link 1807
Favites sp. cf. F. chinensis (Verrill 1866)

Plate 3, figure 3

Favites chinensis Veron and Pichon 1977, p. 53, figs. 83–88 (synonymy)

Five external molds represent fragments having 2–4 small polygonal calices 8–10 mm in diameter with 30–40 septa. The molds are so poor that details of the septa and other structures cannot be determined. The only comparable species on the basis of gross features seems to be *F. chinensis*, in which Veron and Pichon absorbed two other Holocene forms: *Prionastraea acuticollis* Ortmann 1889 and *F. yamanarii* Yabe and Sugiyama 1936. Two fossil species, *Prionastraea dubia* Reuss 1867 from the Miocene of Java, and *F. borneensis* Gerth 1921 from the Pliocene of Borneo and Nias probably belong here.

Age.—Miocene, Midway.

Locality.—Midway, reef hole: 915–916 (with *Favia* sp. B), 940–951 (with *Porites*), 993–994 (with *Stylophora*).

Genus PLESIASTREA Milne Edwards and Haime 1848
Plesiastrea sp. cf. P. curta (Dana 1846)

Plate 2, figure 7

Montastraea curta Chevalier 1971, p. 278, pl. 9, fig. 4, pl. 33, figs. 5, 6; pl. 34, fig. 1; pls. 35, 36 (synonymy)
Veron and Pichon 1977, p. 137, figs. 257–263 (synonymy)

Specimens from five core samples from depths of 754 to 789 ft are most similar to the Holocene *P. curta* of the tropical Pacific. Preservation is poor; most of the original skeletal tissues have been dissolved, leaving only coarse molds that have no external details. Corallites range from 4 to 5 mm in diameter and have thick walls linked by subtabular dissepiments. Septa are thin and are arranged 18/18 to 20/20, the first 18 or 20 extending to a trabecular columella, the remaining 18 or 20 very short, equal, and stout. These characters are like those of Holocene *P. curta* as seen in cross section (pl. 2, fig. 8).

Age.—Miocene, Midway.

Locality.—Midway, reef hole: 754, 762, 768, 778, 789.

Genus CYPHASTREA Milne Edwards and Haime 1848
Cyphastrea ocellina (Dana 1846)

Cyphastrea ocellina Vaughan 1907, p. 103, pl. 25, figs. 4, 5; pl. 26, fig. 1 (synonymy)

Worn fragments of this endemic Hawaiian form were found in the upper 200 ft of the Sand Island drill hole.

Age.—Pliocene and Pleistocene, Midway; Holocene, Hawaii.

Locality.—Midway, Sand Island hole: 125–135, 141–142, 180–185.

Genus GALAXEA Oken 1815
Galaxea haligena Felix 1913

Plate 3, figures 5, 6

Galaxea haligena Felix 1913, p. 339, pl. 26, figs. 1, 2, 2a–c
Felix 1923, p. 89

One specimen, a fragment of a corallum showing nothing of the external surface, is referred to this species, which is possibly an early form of the widespread Pleistocene and Holocene *G. fascicularis* (Linnaeus) of the Indo-Pacific. The corallites range in diameter from 4 to 9 mm, mostly 6 to 8 mm, and have externally faint costal striations. Septa are in four cycles plus a few very short septa of the fifth (48^+), those of the first three extending to and merging with a well-developed

trabecular columella. *G. lauensis* Hoffmeister 1945, from the Miocene of Lau, Fiji, has smaller coraliites and fewer septa.

Age.—Miocene, Midway, Borneo; Pliocene, Java.

Locality.—Midway, reef hole: 494.

REFERENCES CITED

Allison, E. C., Durham, J. W., and Mintz, L. W., 1967, New southeast Pacific echinoids: California Academy of Sciences Occasional Paper 62, 23 p., 32 figs.

Chevalier, J.-P., 1971, Les sclèractiniaires del la Mèlanèsie Francaise. 1er partie: Expédition Française sur les récifs coralliens de la Nouvelle Calèdonie, v. 5, 307 p., 38 pls., 182 figs.

Dana, J. D., 1846–1849, Zoophytes: U.S. Exploring Expedition, v. 7, 740 p., 45 figs.; atlas, 12 p., 61 pls. (1849).

Dana, T. F., 1971, On the reef corals of the world's most northern atoll (Kure: Hawaiian Archipelago): Pacific Science, v. 25, no. 1, p. 80–87, 6 figs.

Duncan, P. M., 1880, Sind fossil corals and *Alcyonaria:* Palaeontologia Indica, ser. 14, v. 1., pt. 1, 110 p., 28 pls.

Ehrenberg, C. G., 1834, Die Corallenthiere des rothen Meeres physiologisch untersucht und systematisch verzeichnet: Akademie der Wissenschaften, Berlin, Abhandlungen 1832, p. 225–380, 1 pl.

Felix, J. P., 1913, Die fossilen Anthozoen aus der Umgegend von Trinil: Palaeontographica, v. 60, p. 311–365, pls. 24–27, 3 figs.

——1921, Fossil Anthozoen von Borneo: Palaeontologie von Timor, pt. 9, no. 15, p. 1–64, pls. 1–6, 12 figs.

Fisher, R. L., ed., 1958, Preliminary report on Expedition Downwind, University of California, Scripps Institution of Oceanography, IGY cruise to the southeast Pacific: IGY [International Geophysical Year] General Report Series, No. 2, 58 p., 21 figs.

Gardiner, J. S., ed., 1903–1906, The fauna and geography of the Maldive and Laccadive Archipelagoes: Cambridge, England, Cambridge University Press, 2 v. (See v. 2, suppl. 1, p. 933–957, pls. 89–93, Madreporaria: Fungida and Turbinolidae.)

Gerth, Heinrich, 1921, Anthozoa, *in* Martin, Karl, Die Fossilen von Java***: Geologische Reichsmuseum Leiden Sammlungen, Neue Folge, v. 1, Abt. 2, no. 3, p. 387–445, pls. 55–57.

——1923, Die Anthozoenfauna des Jungtertiärs von Borneo: Geologische Reichsmuseum Leiden Sammlungen, Ser. 1, v. 10, p. 37–136, 9 pls.

Hoffmeister, J. E., 1945, Corals, *in* Ladd, H. S., and Hoffmeister, J. E., Geology of Lau, Fiji: Bernice P. Bishop Museum Bulletin 181, p. 298–311, pls. 31–40.

Holden, J. C., 1967, Late Cenozoic ostracodes from the drowned terraces in the Hawaiian Islands: Pacific Science, v. 21, no. 1, p. 1–50, 37 figs.

Klunzinger, K. B., 1877–1879, Die Korallenthiere des Rothen Meeres: Berlin, Gutmann'schen, 3 v. (See pts. 2 and 3, 188 p., 20 pls.)

Ladd, H. S., Tracey, J. I., Jr., and Gross, M. G., 1970, Deep drilling on Midway atoll: U.S. Geological Survey Professional Paper 680–A, 22 p.

Maragos, J. E., 1977, Scleractinia, *in* Section 1 *of* Devaney, D. M., and Eldredge, L. G., eds., Reef and shore fauna of Hawaii: Bernice P. Bishop Museum Special Publication 64, p. 158–241, 118 figs.

Matthai, George, 1948, On the mode of growth of the skeleton in fungid corals: Royal Society of London Philosophical Transactions, v. 233–B, p. 177–195, pls. 3–14.

Milne Edwards, Henri, and Haime, Jules, 1857–1860, Histoire naturelle des coralliaires: Paris, Roret, 3 v. and atlas (v. 1, 2 (1857); v. 3 (1860); atlas (1857)).

Ortmann, A. E., 1889, Beobachtungen an Steinkorallen von der südküste Ceylons: Zoologische Jahrbücher, Abteilung für Systematik***, v. 4, p. 493–590, pls. 11–18.

Reuss, A. E., 1867, Ueber fossile Korallen von der Insel Java, *in* Reise der*** "Novara": Geologischer Theil, v. 2, p. 165–185, pls. 1–3.

Scheer, Georg, 1964, Korallen von Abd-el-Kuri: Zoologische Jahrbücher, Abteilung für Systematik***, v. 91, no. 3, p. 451–466, 4 pls., 3 figs.

——1967, Korallen von den Sarso-Inseln im Roten Meer: Senckenbergiana Biologica, v. 48, p. 421–436, 14 figs.

Umbgrove, J. H. F., 1929, Anthozoen van N. O. Borneo: Dutch East Indies, Dienst van den Mijnbouw, Wetenschappelijke Mededeelingen, No. 9, p. 47–78, pls. 1–5, 2 figs.

Vaughan, T. W., 1907, Recent *Madreporaria* of the Hawaiian Islands and Laysan: U.S. National Museum Bulletin 59, 427 p., 96 pls., 1 fig.

Vaughan, T. W., and Hoffmeister, J. E., 1925, New species of fossil corals from the Dominican Republic: Harvard College, Museum of Comparative Zoology, Bulletin, v. 67, no. 8, p. 315–326, 4 pls.

Veron, J. E. N., and Pichon, M., 1976, Scleractinia of eastern Australia. Part I. Families Thamnasteriidae, Astrocoeniidae, Pocilloporidae: Australian Institute of Marine Science Monograph, v. 1, 86 p., 166 figs.

——1977, Scleractinia of eastern Australia. Part II. Families Faviidae and Trachyphylliidae: Australian Institute of Marine Science Monograph, v. 3, 233 p., 477 figs.

Wells, J. W., 1954a, Recent corals of the Marshall Islands: U.S. Geological Survey Professional Paper 260–I, p. 385–486, pls. 94–187, figs. 119–122.

——1954b, Fossil corals from Bikini drill holes: U.S. Geological Survey Professional Paper 260–P, p. 609–617, pls. 223–224, figs. 167–168.

——1964, Fossil corals from Eniwetok Atoll: U.S. Geological Survey Professional Paper 260–DD, p. 1101–1111, pls. 296–300.

Yabe, Hisakatsu, Sugiyama, Toshio, and Eguchi, Motoki, 1936, Recent reef-building corals from Japan and the South Sea Islands under the Japanese Mandate: Tohoku Imperial University Science Reports, 2d ser. (Geology), Special Volume 1, 66 p., 59 pls.

PLATES 1–3

Contact photographs of the plates in this report are available at cost from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

PLATE 1

FIGURES 1–6. *Stylophora pistillata* (Esper) (p. G3).

1. Latex cast, X1. Reef hole, 990–993 ft. USNM 62375.

2, 3. Ecomorph *mordax*, X10, X1. Reef hole 638 ft. USNM 62377.

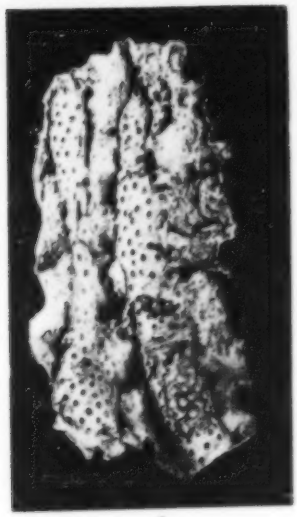
4,5. Ecomorph *mordax*, X1, X5. Reef hole, 699 ft. USNM 62378.

6. Ecomorph *mordax*, mold, X1. Reef hole, 701 ft. USNM 62376.

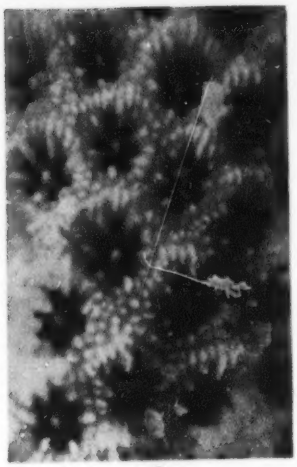
7–9. *Stylophora gemmans* Gerth (p. G4).

7. Mold, X1. Reef hole, 671–676 ft. USNM 62380.

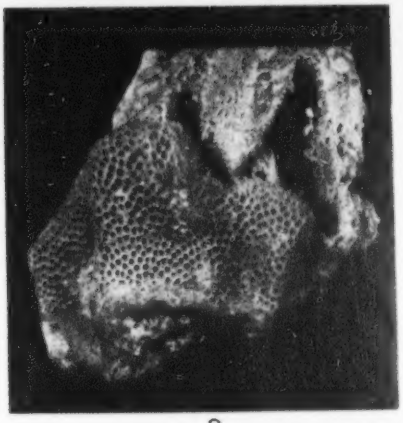
8, 9. Latex cast, X1, X5. Reef hole 970–971 ft. USNM 62379.



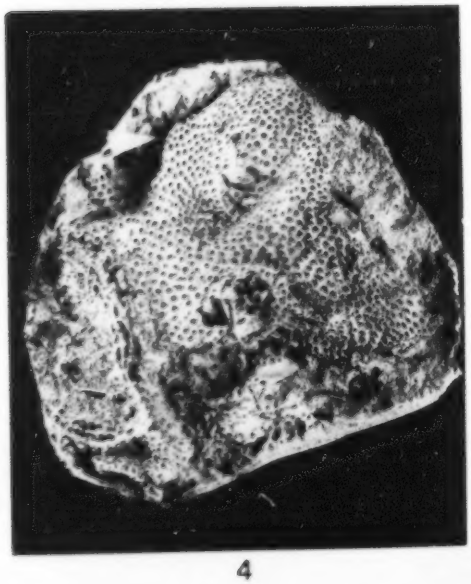
1



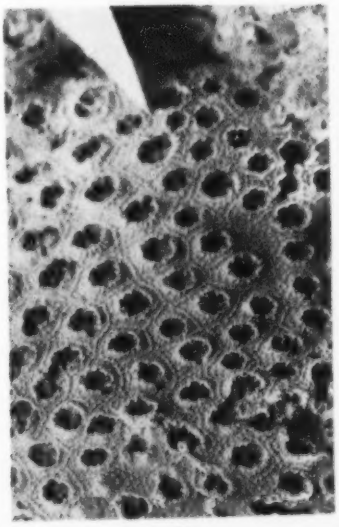
2



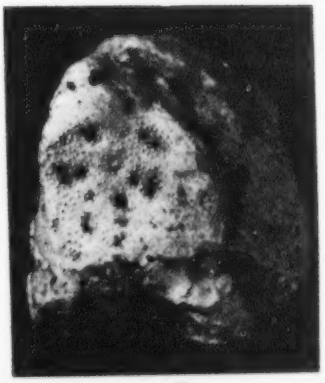
3



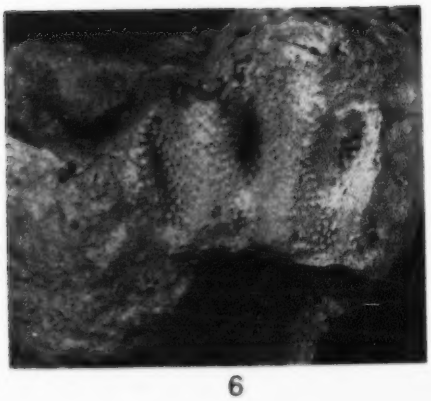
4



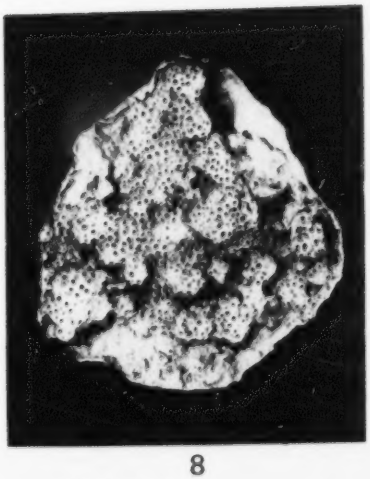
5



7



6



8

9

STYLOPHORA

PLATE 2

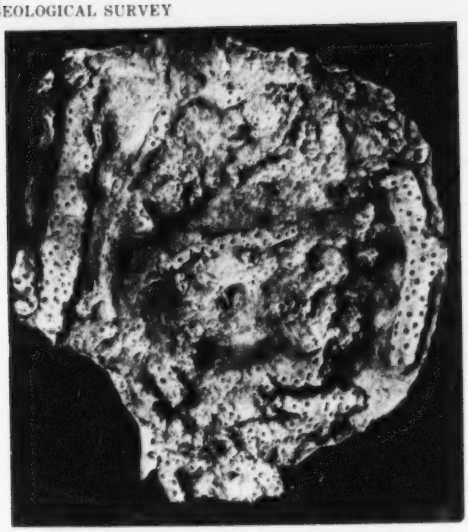
FIGURES 1, 2. *Seriatopora* sp. cf. *S. hystrix* Dana (p. G4).
1. Latex cast, X1. Reef hole, 958–959 ft. USNM 62381.
2. Latex cast, X1. Reef hole, 963–964 ft. USNM 62390.

3, 4. *Pocillopora* sp. cf. *P. hemprichi* Ehrenberg (p. G5).
X1, X5. Reef hole, 631–636 ft. USNM 62388.

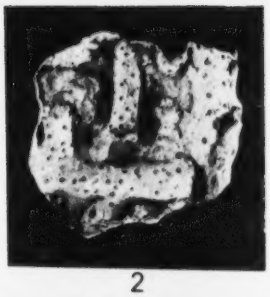
5, 6. *Acropora* sp. (p. G5).
5. Latex cast, X4. Reef hole, 901–906 ft. USNM 62389.
6. Mold, X4. Reef hole, 946–951 ft. USNM 62384.

7. *Plesiastrea* sp. cf. *P. curta* (Dana) (p. G6).
Transverse section, X1. Reef hole, 754.7 ft. USNM 62374.

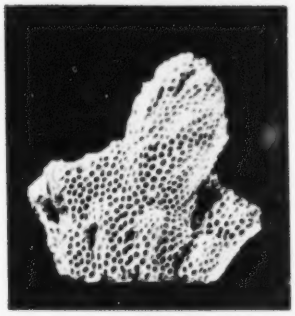
8. *Plesiastrea curta* (Dana) (p. G6).
Transverse section, X1. Holocene, Heron Island, Great Barrier Reefs. USNM 62383.



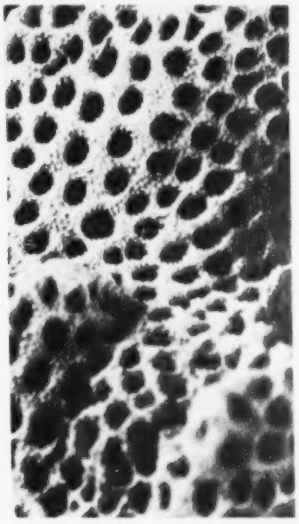
1



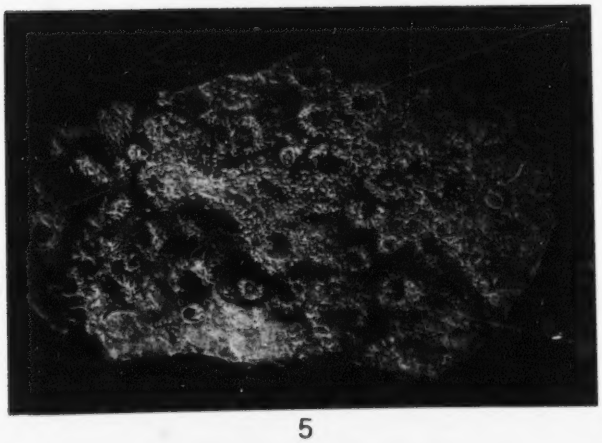
2



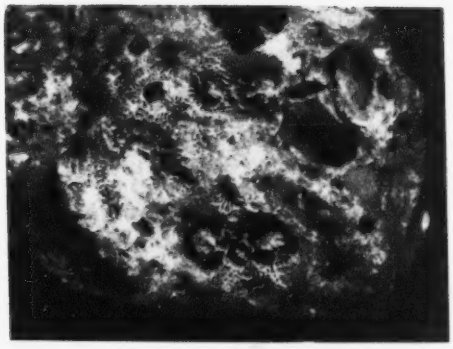
3



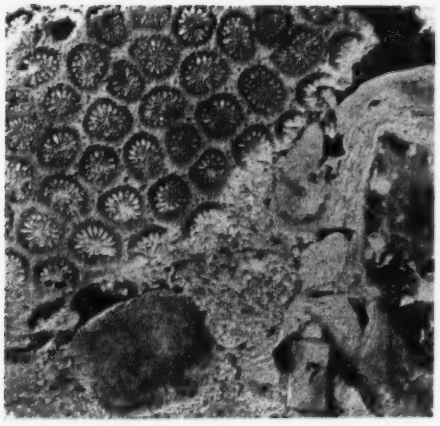
4



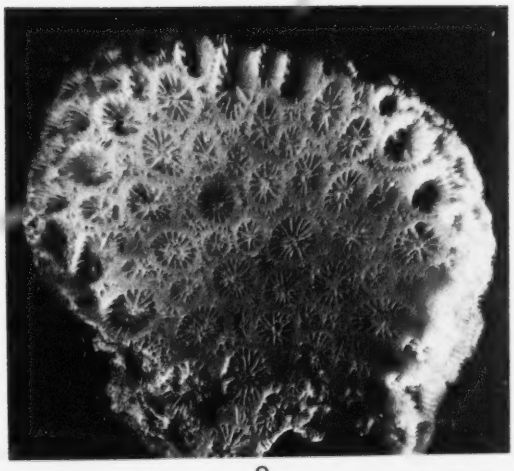
5



6



7



8

SERIATOPORA, POCILLOPORA, ACROPORA, PLESIASTREA

PLATE 3

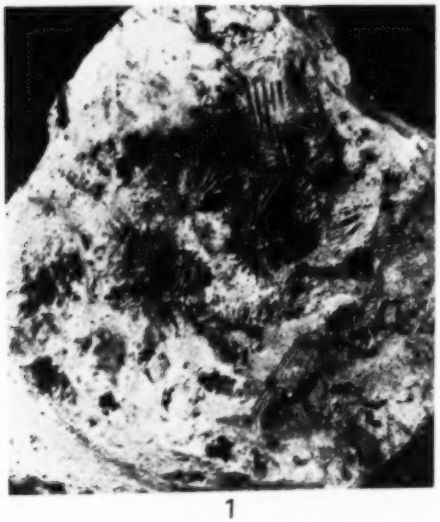
FIGURE 1. *Favia* sp. A (p. G6).
Mold, X1. Reef hole, 1,061-1,066 ft. USNM 62386.

2. *Favia* sp. B (p. G6).
Calices, X1. Reef hole, 915-916 ft. USNM 62382.

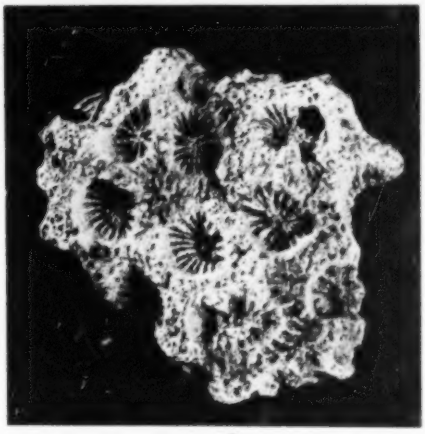
3. *Favites* sp. cf. *F. chinensis* (Verrill) (p. G6).
Mold, X1. Reef hole, 915-916 ft. USNM 62387.

4. *Favia* sp. C (p. G6).
Transverse section, X1. Reef hole, 590-595 ft. USNM 62373.

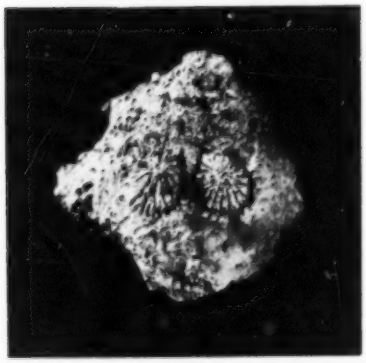
5, 6. *Galaxea haligena* Felix (p. G6).
5. Transverse section, X1. Reef hole, 494 ft. USNM 62385.
6. Vertical section, X1. Reef hole, 494 ft. USNM 62385.



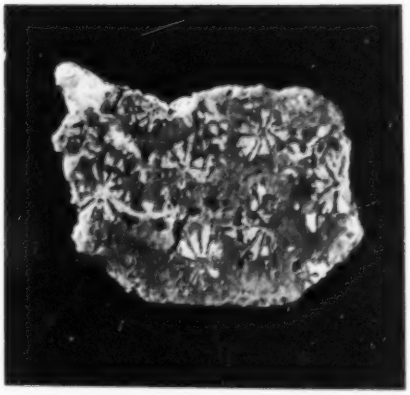
1



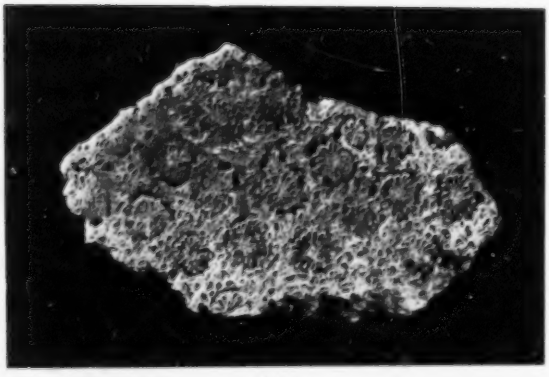
2



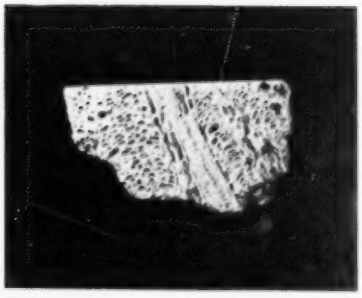
3



4



5



6

FAVIA, FAVITES, GALAXEA

☆U.S. GOVERNMENT PRINTING OFFICE: 1982—361-614/326